

# INTERNATIONAL SEARCH REPORT

International application No  
PCT/JP2006/306992

**A. CLASSIFICATION OF SUBJECT MATTER**  
INV. H03B7/14

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

H03B H03J H01P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, INSPEC

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 617 104 A (DAS ET AL) 1 April 1997 (1997-04-01) column 9, lines 21-33	1,2,5-7
Y	figure 14	8
Y	EP 0 288 135 A (UNITED KINGDOM ATOMIC ENERGY AUTHORITY) 26 October 1988 (1988-10-26) abstract; figure 2	8
	----- -/-	

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

\* Special categories of cited documents :

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
- \*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

\*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

\*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

\*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

\*&\* document member of the same patent family

Date of the actual completion of the international search

19 June 2006

Date of mailing of the international search report

06/07/2006

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

Authorized officer

Robinson, V

## INTERNATIONAL SEARCH REPORT

International application No  
PCT/JP2006/306992

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	UTSUMI Y ET AL: "Dielectric properties of microstrip-line adaptive liquid crystal devices" ELECTRONICS AND COMMUNICATIONS IN JAPAN, PART 2 (ELECTRONICS) SCRIPTA TECHNICA USA, vol. 87, no. 10, 2004, pages 13-24, XP002385402 ISSN: 8756-663X	1,2,5
Y	the whole document	6-8
Y	US 2003/122628 A1 (AIKAWA MASAYOSHI ET AL) 3 July 2003 (2003-07-03) cited in the application	6,7
A	paragraphs [0060] - [0065]; figures 3a-3c, 4a-4c	1-5,8
X	KUKI T ET AL: "Design of a microwave variable delay line using liquid crystal, and a study of its insertion loss" ELECTRONICS AND COMMUNICATIONS IN JAPAN, PART 2 (ELECTRONICS) SCRIPTA TECHNICA USA, vol. 85, no. 2, 2002, pages 36-42, XP002385403 ISSN: 8756-663X	1,2,5
Y	the whole document	6-8
X	PATENT ABSTRACTS OF JAPAN vol. 2003, no. 05, 12 May 2003 (2003-05-12) & JP 2003 017912 A (NIPPON HOSO KYOKAI <NHK>), 17 January 2003 (2003-01-17)	1,5
Y	abstract; figure 1	6-8

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/JP2006/306992

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 5617104	A	01-04-1997	NONE	
EP 0288135	A	26-10-1988	DE 3867686 D1 GB 2202947 A NO 881005 A US 4829233 A	27-02-1992 05-10-1988 12-09-1988 09-05-1989
US 2003122628	A1	03-07-2003	JP 2003204223 A	18-07-2003
JP 2003017912	A	17-01-2003	NONE	

## DESCRIPTION

## INSPECTION APPARATUS USING TERAHERTZ WAVES

## 5 TECHNICAL FIELD

The present invention relates to an inspection apparatus performing analysis of physical properties or the like of an object (hereinafter sometimes referred to as "inspected object") by use of an  
10 electromagnetic wave, and more particularly to an inspection apparatus which is suitable when an electromagnetic wave of a range of millimeter-wave to terahertz-wave is used. Also, the present invention relates to a technique of performing analysis,  
15 identification or the like of an inspected object based on physical property information of the inspected object.

## BACKGROUND ART

20 In recent years, there has been developed a nondestructive inspection technique using a high-frequency electromagnetic wave (hereinafter generally referred to as "terahertz wave" for convenience of description) of a range from millimeter-wave to  
25 terahertz-wave (30GHz-30THz). In the frequency range of the terahertz wave, there exist absorption lines of a variety of substances including biomolecules.

Accordingly, as application fields of electromagnetic waves of this frequency band, there are expected a technique of performing imaging by means of a safer fluoroscopic apparatus as a substitute for X-ray, a  
5 spectral technique of determining an absorption spectrum or complex dielectric constant of the interior of a substance to examine a bonding state, a technique of analyzing biomolecules, a technique of estimating carrier concentration or mobility, and so  
10 on.

As an object inspection apparatus using a terahertz wave, there has been disclosed, as shown in FIG. 9, an apparatus for irradiating an object 4 with a terahertz wave propagating through a space and  
15 identifying the constituent material of the object 4 based on a change in the characteristics of the wave transmitted through the object 4 (Japanese Patent Application Laid-Open Nos. H08-320254 and 2002-257629). At this time, the object 4 can be two-  
20 dimensionally scanned to provide a transmission image of the interior of the object 4.

Further, although not using the frequency range of the terahertz wave, there has been disclosed a technique relating to an inspection apparatus  
25 obtained by integrating such an inspection apparatus (Japanese Patent Application Laid-Open No. H06-018421). As shown in FIG. 10, in this device 11,

semiconductors 1, 6 having light emitting elements 2 and light receiving elements 7, respectively, are joined and integrated with a gap corresponding to a flow path 10 being present therebetween. The device  
5 11 measures the concentration of an objective component existing in the flow path 10 based on a change in a light propagating from the light emitting elements 2.

Moreover, as a constitutional example of an  
10 optically gated terahertz transmitter/receiver for transmitting/receiving a terahertz wave, an antenna structure formed on a semiconductor substrate, as shown in FIGS. 11A and 11B, is used in many cases. When transmitting a terahertz wave, as shown in FIG.  
15 11A, a gap between dipole antennas of a PC antenna is irradiated with a laser light under application of a DC bias voltage between transmission lines. On the other hand, when receiving a terahertz wave, as shown in FIG. 11B, in a state in which a gap between dipole  
20 antennas of a PC antenna is irradiated with a laser light, an electric current flow between transmission lines generated by incidence of a terahertz wave on a substrate is measured by an ammeter.

Water has a strong absorption spectrum for the  
25 terahertz wave. Accordingly, as with Japanese Patent Application Laid-Open No. H08-320254 above, when a terahertz wave is allowed to propagate through the

atmosphere, the electromagnetic wave will be remarkably attenuated by the influence of water existing in the atmosphere. To reduce the influence of the atmosphere on an electromagnetic wave, there is needed, for example, a means of adjusting the environment at least with respect to a region surrounding the propagation path of the electromagnetic wave. In this case, there is a problem that the provision of the means of adjusting the environment makes the apparatus large-sized. Also, there is another problem that the characteristics of substances present in the atmosphere are liable to be simultaneously detected to thereby sense unwanted signal components, thus increasing noise components.

#### DISCLOSURE OF THE INVENTION

In view of the above problems, an object of the present invention is to provide an inspection apparatus having reduced electromagnetic wave attenuation.

Accordingly, the present invention provides an inspection apparatus comprising:

- a substrate having therein a structure for holding an inspected object;
- an electromagnetic wave transmitting portion having an antenna structure for irradiating the

inspected object with an electromagnetic wave; and  
an electromagnetic wave receiving portion  
having an antenna structure for receiving the  
electromagnetic wave,

5 wherein the electromagnetic wave transmitting  
portion and the electromagnetic wave receiving  
portion are disposed in contact with the substrate.

In the present invention, it is preferred that  
the inspection apparatus is configured such that an  
10 electromagnetic wave generated in the electromagnetic  
wave transmitting portion propagates through the  
substrate, and the electromagnetic wave receiving  
portion receives an electromagnetic wave which is  
changed when the inspected object is disposed in an  
15 electromagnetic wave propagation path.

According to the present invention, there is  
obtained the effect that the electromagnetic wave  
attenuation resulting from an environment surrounding  
the inspection apparatus can be suppressed. Further,  
20 because a structure is adopted in which an unwanted  
substance is readily prevented from being  
contaminated into an electromagnetic wave propagation  
path, there is also obtained the effect that the  
detection sensitivity improves.

25

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A, 1B and 1C are a plan view, a side



view and a rear view for explaining an inspection apparatus according to an embodiment and Example 1 of the present invention, respectively;

FIG. 2 is a diagram showing an exemplary  
5 configuration of an inspection apparatus according to the present invention;

FIG. 3 is a cross-sectional view for explaining an inspection apparatus according to Example 2 of the present invention;

10 FIG. 4 is a plan view for explaining a modified example of the inspection apparatus according to the example of the present invention;

FIG. 5 is a plan view for explaining a modified example of the inspection apparatus according to the  
15 example of the present invention;

FIG. 6 is a schematic view for explaining an example of the production steps of an inspection apparatus according to the present invention;

FIG. 7 is a graphical representation for  
20 explaining the operation of the inspection apparatus according to Example 1 of the present invention;

FIG. 8 is a graphical representation for explaining the operation of the inspection apparatus according to Example 2 of the present invention;

25 FIG. 9 is a view for explaining the background art of an inspection apparatus using a terahertz wave;

FIG. 10 is a cross-sectional view for explaining the background art of an inspection apparatus using light; and

FIG. 11A is a schematic diagram for explaining a method of transmitting a terahertz wave using a photoconductive antenna (PC antenna), and FIG. 11B is a schematic diagram for explaining a method of receiving a terahertz wave using a PC antenna.

#### 10 BEST MODE FOR CARRYING OUT THE INVENTION

Specific configurations for carrying out the present invention will be described with reference to the drawings. Incidentally, like reference numerals will refer to like elements in the respective figures.

15 FIGS. 1A, 1B and 1C are a plan view, a side view and a rear view for showing a schematic configuration of an inspection apparatus according to one embodiment of the present invention, respectively. As shown in FIGS. 1A, 1B and 1C, the inspection  
20 apparatus 100 according to the present embodiment has a configuration in which a THz wave transmitting portion 101 and a THz wave receiving portion 102 are disposed in contact with the surfaces of an inspected object holding portion 103 (hereinafter sometimes  
25 referred to as "substrate") having therein a structure for holding an inspected object 104. The inspected object 104 is held within the structure.

which the inspected object holding portion 103 has inside thereof. In the present embodiment, as shown in FIGS. 1A, 1B and 1C, the interior structure of the inspected object holding portion 103 for holding the inspected object 104 has a cylindrical shape, but is not limited to this shape. Any structure capable of holding the inspected object 104 within the inspected object holding portion 103 can be used. Further, it is preferable that the inspected object holding portion 103 has a structure which allows the inspected object 104 to be inserted from the outside.

The inspected object holding portion 103 is fabricated by using a processing technique applied to an ordinary MEMS (Micro Electro Mechanical Systems) fabrication technique or the like. For example, as shown in FIG. 6, a technique is employed in which recess portions are formed in part of two substrates for constituting an inspected object holding portion 103, and thereafter the two substrates are bonded and integrated by use of a resin adhesive layer 601 with the recess portions facing each other. However, it should be noted that the technique of bonding the substrates is not limited to the one using the resin adhesive 601, and any technique or system using a substance capable of bonding and integrating the substrates can be used. Further, the technique is not limited to such bonding, and any technique can be

employed which allows a structure for holding an inspected object 104 to be formed in the interior of the inspected object holding portion 103.

The THz wave transmitting portion 101 and THz  
5 wave receiving portion 102 each have an antenna structure comprised of a conductor. For example, in the present embodiment, as shown in FIGS. 1A, 1B and 1C, a structure is employed in which two triangular conductors are opposed to each other with the  
10 vertexes facing each other with a minute gap (not shown) therebetween. This antenna configuration is called a bow-tie antenna, and known as a wide-band antenna which functions as an antenna with respect to an electromagnetic wave signal of a higher frequency  
15 than a wavelength calculated from the antenna height  $H$  (corresponding to a distance between the bases of the triangles). Further, it is also known that the antenna impedance varies depending on the center angle  $\theta$  of the antenna.

20 Of course, the antenna structure according to the present embodiment is not limited thereto, and appropriately selected depending on required characteristics such as band, directivity and impedance matching. In the present embodiment, as  
25 described above, the center portion of the antenna structure has a minute gap, and as described in BACKGROUND ART above with reference to FIGS. 11A and

11B, the gap is optically gated to generate and detect an electromagnetic wave (when generating it, a bias voltage is applied to the gap, and when detecting it, a laser light is irradiated to the gap).

5 However, it should be noted that such structure is also appropriately selected according to the technique of generating/detecting a terahertz wave. Such structure is fabricated by use of an ordinary print technique. However, the technique is not  
10 limited thereto and it is only necessary to be capable of forming a desired conductor pattern.

In the THz wave transmitting portion 101, the gap of the antenna structure is optically gated to generate an electromagnetic wave. For example, it is  
15 known that when a GaAs substrate having low-temperature-grown GaAs (LT-GaAs) epitaxially grown on a surface thereof is used as the inspected object holding portion 103, the electromagnetic wave band exists in the terahertz wave region. However, the  
20 material used for the inspected object holding portion 103 is not limited thereto. According to the desired electromagnetic wave characteristics, the structure and processing conditions of the inspected object holding portion 103, and the like, appropriate  
25 selection is made from, for example, a substrate having a gain structure capable of achieving an electromagnetic wave gain, a substrate obtained by

transferring a LT-GaAs epitaxially grown thin film on a desired substrate such as a Si substrate, and the like.

As described above, electromagnetic waves are  
5 liable to be confined within the substrate due to a difference in refractive index at an interface with the atmosphere or the like, so that most of the generated terahertz waves propagate within the inspected object holding portion 103. When an  
10 inspected object 104 exists in a terahertz wave propagation path, and when a frequency absorption spectrum specific to the inspected object 104 exists within the terahertz wave region, a part of frequency components of the terahertz wave propagating within  
15 the inspected object holding portion 103 is absorbed, so that the propagation state of the terahertz wave will change. The change includes changes in parameters such as phase, intensity, and waveform of the electromagnetic wave. It is preferable that the  
20 absorption spectrum of the inspected object 104 exists within the terahertz wave region. However, even when the absorption spectrum of the inspected object 104 does not exist within the terahertz wave region, the propagation state of the terahertz wave  
25 propagating within the inspected object holding portion 103 will change due to physical characteristics (for example, refractive index of

loss) of the inspected object 104. Such change is detected by the THz wave receiving portion 102.

In the THz wave receiving portion 102, as described above, by optically gating the gap of the antenna structure constituting the portion, a terahertz wave propagating within the inspected object holding portion 103 is detected. In the present embodiment, to generate/detect an electromagnetic wave in the terahertz wave region, the optical gating system described above is used. However, the technique is not limited to such a system, and it is only necessary to be capable of generating/detecting an electromagnetic wave in the terahertz wave region (see Examples described below).

Further, as shown in FIGS. 1A to 1C, in the present embodiment, the THz wave transmitting portion 101 and the THz wave receiving portion 102 are disposed face each other with the inspected object holding portion 103 (i.e., substrate) therebetween. When the THz wave transmitting portion 101 and the THz wave receiving portion 102 are disposed along a direction perpendicular to the thickness direction of the substrate (i.e., parallel to the principal surface of the substrate) in this way, the propagation distance of the terahertz wave can easily be varied by changing the thickness of substrate, which is preferable. However, the configuration is

not limited thereto. For example, the two portions may be disposed on the same surface of the inspected object holding portion 103. Further, when disposed facing each other, the THz wave transmitting portion 101 and THz wave receiving portion 102 may be offset with respect to each other. It is only necessary that the two portions are disposed such that a terahertz wave generated in the THz wave transmitting portion 101 and propagating through the inspected object holding portion 103 via an inspected object 104 can be received by the THz wave receiving portion 102.

There will be described below an embodiment adapted to an inspection apparatus which, by use of the aforementioned inspection apparatus 100, practically acquires physical property information of an inspected object 104 and performs analysis, identification or the like of the inspected object 104.

As schematically shown in FIG. 2, in the inspection apparatus according to the present embodiment, generation means 201 for generating a electromagnetic wave and detection means 202 for detecting an electromagnetic wave are additionally connected to the inspection apparatus 100. As the generation means 201 in the present embodiment, there may be used any device or apparatus of any



configuration as long as it allows the THz wave transmitting portion 101 constituting the inspection apparatus 100 to generate a terahertz wave. For example, when the THz wave transmitting portion 101

5 has an antenna conductor structure having a gap as described above, the generation means 201 corresponds to a light source and an optical system for gating the gap, and a bias applying power source. Similarly, as the detection means 202 in the present embodiment,

10 there may be used any device or apparatus of any configuration as long as it can detect a terahertz wave received by the THz wave receiving portion 102 constituting the inspection apparatus 100. For example, when the THz wave receiving portion 102 has

15 an antenna conductor structure having a gap as described above, the detection means 202 corresponds to a light source and an optical system for gating the gap, and a current detection means.

Specifically, as the light source of the

20 detection means 202, a femtosecond laser light source is used. Further, the current detection means is constituted of a current input preamplifier and an information processing device for forming a waveform of a terahertz wave. When the gap between antennas

25 is gated by a laser generated by the light source, the current input preamplifier detects a current corresponding to the electric field strength of a

terahertz wave incident on the antenna. However, this current signal has a current value at the moment when gated. Therefore, an optical delay system, for example, is used to vary the timing of laser incidence on the antenna gap and the waveform is observed. In the information processing device, current values at respective laser timing are plotted in a time domain to form a terahertz wave. That is, this corresponds to sampling/detection of a terahertz wave with a short-pulse laser. A spectroscope using this technique is generally called a terahertz-wave time-domain spectroscope (THz-TDS). In the detection means 202, a terahertz wave is detected by use of such technique.

Moreover, in the inspection apparatus according to the present embodiment, to the inspection apparatus 100, there is further provided a configuration which uses an inspected object insertion means 203 for inserting an inspected object 104 from the outside into the inspected object holding portion 103 of the inspection apparatus 100. As the inspected object insertion means 203, any means of any configuration can be employed as long as it can achieve the object of inserting into the inspected object holding portion 103 an inspected object used for analysis. Examples of such means include a technique of using an actuator to perform

insertion, a technique of using inkjet technology to perform insertion by jetting, a technique of using a needle to perform insertion, and a technique of using a physical phenomenon at an interface such as a  
5 capillary phenomenon to perform insertion.

The detection means 202 acquires from the THz wave receiving portion 102 the waveform of a terahertz wave which has propagated through the inspected object holding portion 103 and whose  
10 propagation state has been varied by the presence of the inspected object 104. An inspected object analyzing portion 204 compares the information on the terahertz wave acquired by the detection means 202 with the information on a substance preliminarily  
15 stored in a database 205 to perform analysis, identification or the like of the inspected object. For example, the inspected object analyzing portion 204 can compare the frequency spectrum of the terahertz wave acquired by the detection means 202  
20 with the frequency spectrum of the substance stored in the database 205 to identify the constitutional components of the inspected object. However, the information to be compared is not limited thereto, and an information to intensity variation or phase  
25 variation can also be used. Further, it is preferable that data of as many substances as possible are stored in the database 205.

In the present embodiment, attention is paid, particularly, to a terahertz wave. However, it will easily be appreciated that the inspection apparatus according to the present invention can also be  
5 applied to electromagnetic wave outside the terahertz frequency region.

The inspection apparatus according to the present embodiment, because of having the configuration and operation as described above, can  
10 perform analysis, identification or the like of an inspected object 104 without causing a terahertz wave for detection purpose to propagate through an environment surrounding the inspection apparatus. Accordingly, attenuation of the terahertz wave can be  
15 suppressed, so that there is obtained the effect such that the signal strength is increased to facilitate the detection operation.

Moreover, because an unwanted substance can readily be prevented from being contaminated into a terahertz  
20 wave propagation path, there is also obtained the effect that noise components (in the case of the present embodiment, a change in the propagation state of the electromagnetic wave caused by an unwanted substance) are suppressed to improve the detection  
25 sensitivity. Moreover, it is also possible to make the inspection apparatus small-sized.

[Examples]

More specific examples will be described below with reference to the drawings.

(Example 1)

FIGS. 1A, 1B and 1C show one example of an inspection apparatus according to the present invention. Incidentally, it is noted that, in the present example, the operation verification of an inspection apparatus is performed by calculation using an electromagnetic field simulator.

As shown in FIGS. 1A, 1B and 1C, the inspection apparatus 100 of the present example is constituted by a THz wave transmitting portion 101, a THz wave receiving portion 102, and an inspected object holding portion 103. The THz transmitting portion 101 and THz receiving portion 102 each have a bow-tie type antenna structure in which conductors each having an isosceles triangle shape with a vertical angle  $\theta=90^\circ$  are disposed in opposition to each other. The antenna structure of the present example has an antenna height H of 1 mm. In the present example, the antenna structure has a gap (not clearly shown in the figures) of 5  $\mu\text{m}$  at the center thereof (i.e., between the vertexes of the two triangular conductors). In the present example, the antenna structures are formed by an evaporation process using AuGe/Ni/Au so as to face each other with the inspected object holding portion 103 therebetween, as

shown in FIGS. 1A, 1B and 1C.

The inspected object holding portion 103 is a substrate for holding an inspected object 104 in a space provided therein such that the inspected object  
5 104 fills the space so as to leave substantially no empty space. As shown in FIG. 6, the inspected object holding portion 103 is obtained by forming, by use of the processing technique such as described above, a recess portion having a semi-cylindrical  
10 shape of 60  $\mu\text{m}$  in radius in a surface of a GaAs substrate of 100  $\mu\text{m}$  in thickness having an LT-GaAs epitaxially grown layer of 1.5  $\mu\text{m}$  in thickness thereon, and then bonding and integrating the thus processed two substrates by use of a resin adhesive  
15 601. As a result, a cylindrical space of 60  $\mu\text{m}$  in radius is fabricated within the thus bonded GaAs substrate of 200  $\mu\text{m}$  in thickness.

In the present example, as the THz wave transmitting portion 101 and the THz wave receiving  
20 portion 102, the antenna structures having the gap are used. Accordingly, as described above, by optically gating the gap portion, an electromagnetic wave can be generated/detected. At this time, the electromagnetic wave will be a terahertz wave. In  
25 order to optically gate the gap portion of the antenna structure in this manner, a femtosecond laser is used as the generation means 201 (see FIG. 2) of

the inspection apparatus, and the detection means 202 (see FIG. 2) of the inspection apparatus is constituted of an optical device having an optical delay system in which an femtosecond laser light is  
5 time delayed.

In the inspection apparatus 100 constituted as described above, an inspected object 104 is inserted in the cylindrical space. Thus, the inspection apparatus shown in FIG. 2 can detect a terahertz wave  
10 whose propagation state has been varied by the presence of the inspected object 104; and in the inspected object analyzing portion 204, the information stored in the database 205 is referred to, whereby analysis, identification or the like of the  
15 inspected object 104 becomes possible.

FIG. 7 is a graphical representation obtained by calculating the state of propagation of a terahertz wave from the THz wave transmitting portion 101 to the THz wave receiving portion 102 when DNA  
20 (dielectric constant: 4.0; dielectric loss tangent ( $\tan\delta$ ): 0.01) is used as the inspected object 104. Referring to FIG. 7, the solid line indicates the propagation state of terahertz wave when the inspected object 104 is present, and the broken line  
25 indicates the propagation state of terahertz wave when the inspected object 104 is absent. As is clearly seen from FIG. 7, the frequency

characteristics of the terahertz wave are shifted to the lower frequency side by the presence of the inspected object 104. It can also be seen that the intensity (transmittance) also varies depending on  
5 the frequency. In this calculation, as the physical characteristics of the inspected object 104, only the dielectric constant and dielectric loss tangent are considered. However, when an effect of absorption of an electromagnetic wave depending on frequency  
10 spectrum specific to this inspected object 104 is considered, it can be expected that a more noticeable change in the frequency spectrum occurs.

In the present example, the THz wave transmitting portion 101 and the THz wave receiving  
15 portion 102 are disposed to face each other via the inspected object holding portion 103. However, the present invention is not limited to such arrangement. For example, as described above, when the effect of terahertz wave confinement in the inspected object  
20 holding portion 103 is utilized, even when the THz wave transmitting portion 101 and the THz wave receiving portion 102 are fabricated on the same surface of the inspected object holding portion 103, a terahertz wave can be detected in the THz wave  
25 receiving portion 102. Further, when such terahertz wave confinement effect is applied, an inspected object 104 contained in the inspected object holding



portion 103 does not always have to be disposed just under the THz wave transmitting portion 101, and the THz wave transmitting portion 101 and the THz wave receiving portion 102 can be disposed at any positions. Moreover, when the apparatus is controlled such that the operations of the generation means 201 and detection means 202 constituting the inspection apparatus are alternately performed, the generation/detection operation can be performed by either one of the THz wave transmitting portion 101 and the THz wave receiving portion 102.

Also, in the present example, as the technique for generating/detecting a terahertz wave, a technique is described in which a femtosecond laser is used to perform optical gating. However, the present invention is not limited to this technique. For example, the following configuration can be employed.

As shown in FIG. 4, a configuration may be employed which a negative resistance element 401 is provided at the center portion of the THz wave transmitting portion 101 and the THz wave receiving portion 102. The negative resistance element 401 is a semiconductor device, as typified by a resonant tunneling diode (RTD) or a Gunn diode, capable of achieving an electromagnetic wave gain. In such a configuration, a bias voltage can be applied from

outside to the negative resistance element 401 to generate a terahertz wave in the THz wave transmitting portion 101 and to detect the terahertz wave in the THz wave receiving portion 102. When  
5 such an inspection apparatus 400 is used, the generation means 201 for generating a terahertz wave and the detection means 202 for detecting a terahertz wave of the inspection apparatus are each constituted by a bias circuit.

10 In addition, in the aforementioned example, the THz wave transmitting portion 101 and the THz wave receiving portion 102 are constituted so as to function also as elements for generating/detecting a terahertz wave. However, as shown in FIG. 5, a  
15 configuration may be employed in which a high frequency circuit 501 having a function of generating or detecting a terahertz wave is connected to the THz wave transmitting portion 101 or the THz wave receiving portion 102 via a waveguide.

20 As described above, in the inspection apparatus of the present example, analysis, identification, or the like of an inspected object can be performed without causing a terahertz wave to propagate through the environment surrounding the inspection apparatus.  
25 Thus, the attenuation of a terahertz wave can be suppressed, so that the signal intensity increases to thereby facilitate the detection operation. Further,

an unwanted substance is readily prevented from being contaminated into the terahertz wave propagation path, so that noise components (in the case of the present example, a change in the propagation state of the electromagnetic wave caused by an unwanted substance) are suppressed to thereby improve the detection sensitivity. Moreover, by utilizing the terahertz wave confinement effect, there is obtained the effect that the degree of freedom in layout of the elements used to generate/detect a terahertz wave is increased. Furthermore, by performing the generation/detection operation using a single antenna structure, there is obtained the effect that the inspection apparatus production steps can be decreased to thereby reduce the production cost. In addition, by incorporating a semiconductor device having an electromagnetic wave gain into the inspection apparatus, optical components of the inspection apparatus used for generating/detecting a terahertz wave can be remarkably decreased, so that there is obtained the effect that the size of the apparatus can easily be reduced.

(Example 2)

FIG. 3 shows a second example of the inspection apparatus according to the present invention. Incidentally, it is noted that, also in the present example, the operation verification of an inspection

apparatus is performed by calculation using an electromagnetic field simulator. As shown in FIG. 3, the inspection apparatus 300 is constituted by a THz wave transmitting portion 101, a THz wave receiving portion 102, and an inspected object holding portion 301. Referring to FIG. 3, a major difference between the inspection apparatus of Example 1 described above and the inspection apparatus 300 of the present example lies in that a plurality of structures, formed in the inspected object holding portion 301, for holding an inspected object 104 (not shown) are periodically disposed to form a resonant structure.

As with Example 1 above, the THz transmitting portion 101 and THz receiving portion 102 each have a bow-tie type antenna structure in which conductors each having an isosceles triangle shape with a vertical angle  $\theta=90^\circ$  are disposed in opposition to each other. Further, the antenna structure of the present example has an antenna height H of 1 mm.

Also in the present example, the antenna structure has a gap (not clearly shown in the figures) of 5  $\mu\text{m}$  at the center thereof (i.e, between the vertexes of the two triangular conductors). Moreover, the antenna structures are formed by an evaporation process using AuGe/Ni/Au so as to face each other with the inspected object holding portion 301 having the resonant structure within a GaAs substrate of 200

$\mu\text{m}$  in thickness having an LT-GaAs epitaxially grown layer of  $1.5 \mu\text{m}$  in thickness on the surface thereof therebetween, as with Example 1.

In the present example, the structure of the  
5 resonant portion of the inspected object holding  
portion 301 is such that cylindrical spaces of  $9 \mu\text{m}$   
in radius are disposed at intervals of  $40 \mu\text{m}$  in a  
triangular lattice arrangement. Such a structure can  
be well fabricated by the current MEMS technique. By  
10 holding an inspected object 104 by means of such a  
resonant structure, a terahertz wave propagating  
through the inspected object holding portion 301 is  
strongly localized in a portion in which the  
inspected object 104 is present, so that the  
15 interaction with the inspected object 104 is  
increased. Consequently, the change, caused by the  
inspected object 104, in the propagation state of a  
terahertz wave propagating within the inspected  
object holding portion 103 can also be made more  
20 noticeable.

Also in the present example, because the  
antenna structures having the gap are used as the THz  
wave transmitting portion 101 and THz wave receiving  
portion 102, when the gap portion is optically gated,  
25 an electromagnetic wave can be generated/detected.  
At this time, the electromagnetic wave will be a  
terahertz wave. In this manner, similarly to Example

1 described above, the gap portion of the antenna structure is optically gated.

With the inspection apparatus 300 constituted as described above, an inspected object 104 is  
5 inserted into the cylindrical spaces as periodically disposed. Thereby, the inspection apparatus shown in FIG. 2 can detect a terahertz wave whose propagation state has been varied by the presence of the inspected object 104, so that analysis,  
10 identification, or the like of the inspected object 104 can be performed in the inspected object analyzing portion 204 by referring to the information stored in the database 205.

FIG. 8 is a graphical representation obtained  
15 by calculating the state of propagation of a terahertz wave from the THz wave transmitting portion 101 to the THz wave receiving portion 102 when DNA (dielectric constant: 4.0; dielectric loss tangent ( $\tan\delta$ ): 0.01) is used as the inspected object 104.  
20 Referring to FIG. 8, the solid line indicates the propagation state of terahertz wave when the inspected object 104 is present, and the broken line indicates the propagation state of terahertz wave when the inspected object 104 is absent. As is  
25 clearly seen from FIG. 8, the frequency characteristics of the terahertz wave are shifted to the lower frequency side by the presence of the

inspected object 104. Particularly, in the present example, the configuration of the resonant structure is designed such that the resonant frequency is at about 1 THz. Referring to FIG. 8, it can be seen  
5 that the intensity of frequency components in the vicinity of 1.03 THz remarkably changes due to the presence of the inspected object 104. In this calculation, as the physical characteristics of the inspected object 104, only the dielectric constant  
10 and dielectric loss tangent are considered. However, when an effect of absorption of an electromagnetic wave depending on frequency spectrum specific to this inspected object 104 is considered, it can be expected that a more noticeable change in the  
15 frequency spectrum occurs.

In the present embodiment, as the structure of the inspected object holding portion 103, there is used a resonant structure in which cylindrical spaces are disposed in a triangular lattice arrangement.  
20 However, the present invention is not limited to this structure. For example, in place of the cylindrical spaces, there may be used spaces of another shape such as a square pole shape or the like. Further, the manner of disposition is not limited to a  
25 triangular lattice arrangement, and a square lattice arrangement may also be employed. In short, any configuration can be employed as long as a resonant

action can be achieved by periodical arrangement of the spaces in the inspected object holding portion 301. Moreover, in a part of the periodical arrangement of spaces, there may exist a structure which disturbs the periodicity. This is obtained by, for example, disposing within a photonic band gap structure, a periodicity-disturbing structure which allows only an electromagnetic wave of a particular frequency to pass therethrough. Thereby, the influence of the inspected object 104 on the electromagnetic wave of the particular frequency can be measured more noticeably.

In addition, also in the present example, as the technique of generating/detecting a terahertz wave, there is described a configuration in which optical gating is performed by use of a femtosecond laser. However, the present invention is not limited to this technique. For example, the aforementioned configuration shown in FIG. 4 can also be employed. Further, also in Example 2, the THz wave transmitting portion 101 and the THz wave receiving portion 102 are constructed so as to function also as elements for generating/detecting a terahertz wave. However, they may have a constitution such as shown in FIG. 5 above.

The inspection apparatus of Example 2 as described above has the following advantageous effect



in addition to the effects described above for  
Example 1. By localizing a terahertz wave in a  
portion in which an inspected object exists, the  
interaction between the terahertz wave and the  
5 inspected object can be intensified, thus improving  
the detection sensitivity and facilitating analysis  
or identification with a higher accuracy.

10 This application claims priority from Japanese  
Patent Application No. 2005-087326 filed on March 24,  
2005, which is hereby incorporated by reference  
herein.

## CLAIMS

1. An inspection apparatus comprising:  
a substrate having therein a structure for holding an inspected object;  
5 an electromagnetic wave transmitting portion having an antenna structure for irradiating the inspected object with an electromagnetic wave; and  
an electromagnetic wave receiving portion having an antenna structure for receiving the  
10 electromagnetic wave,  
wherein the electromagnetic wave transmitting portion and the electromagnetic wave receiving portion are disposed in contact with the substrate.
2. The inspection apparatus according to claim  
15 1, wherein an electromagnetic wave generated in the electromagnetic wave transmitting portion propagates through the substrate, and the electromagnetic wave receiving portion receives an electromagnetic wave which is changed when the inspected object is  
20 disposed in an electromagnetic wave propagation path.
3. The inspection apparatus according to claim  
1, wherein the structure for holding the inspected object comprises a plurality of portions for holding the inspected object periodically disposed.
- 25 4. The inspection apparatus according to claim 1, wherein at least one of the electromagnetic wave transmitting portion and the electromagnetic wave

receiving portion comprises a negative resistance element.

5. The inspection apparatus according to claim 1, wherein at least one of the electromagnetic wave transmitting portion and the electromagnetic wave receiving portion is connected to a high frequency circuit via a waveguide for allowing an electromagnetic wave to propagate therethrough.

6. The inspection apparatus according to claim 1, wherein the electromagnetic wave transmitting portion and the electromagnetic wave receiving portion have a common structure and have both a function of transmitting an electromagnetic wave and a function of receiving an electromagnetic wave.

7. The inspection apparatus according to claim 1, wherein the electromagnetic wave is a terahertz wave.

8. The inspection apparatus according to claim 1, further comprising:

generation means for allowing the electromagnetic wave transmitting portion to generate an electromagnetic wave of a desired frequency band;

detection means for allowing the electromagnetic wave receiving portion to detect an electromagnetic wave propagated through the substrate;

a database for preliminarily storing physical

characteristics of the inspected object; and

an analyzing portion for collating an  
information to an electromagnetic wave detected by  
the detection means with an information stored in the  
5 database to inspect the inspected object.

9. The inspection apparatus according to claim  
8, wherein the generation means is a laser oscillator.

10. The inspection apparatus according to claim  
1, wherein the electromagnetic wave transmitting  
10 portion and the electromagnetic wave receiving  
portion are formed along a direction perpendicular to  
a thickness direction of the substrate.

11. An inspection apparatus comprising:  
a substrate having therein a structure for  
15 holding an inspected object;  
an electromagnetic wave transmitting portion  
having an antenna structure for irradiating the  
inspected object with an electromagnetic wave; and  
an electromagnetic wave receiving portion  
20 having an antenna structure for receiving the  
electromagnetic wave,

wherein the electromagnetic wave transmitting  
portion and the electromagnetic wave receiving  
portion are integrated with the substrate.

FIG. 1A

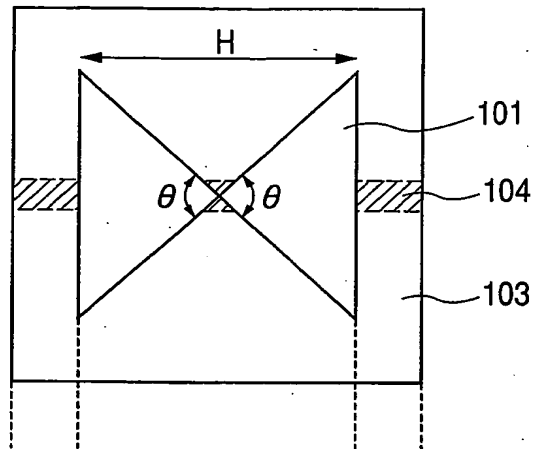


FIG. 1B

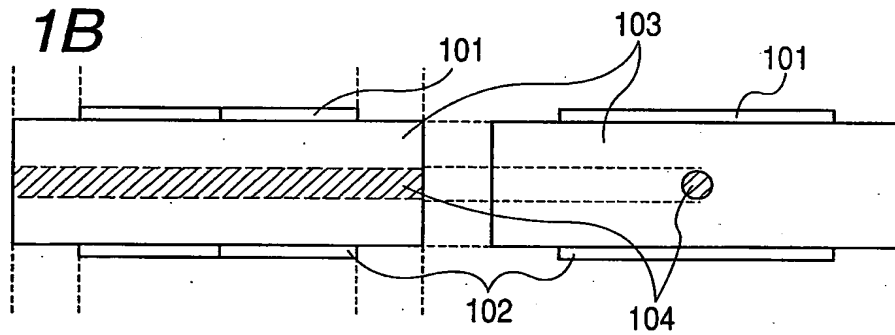
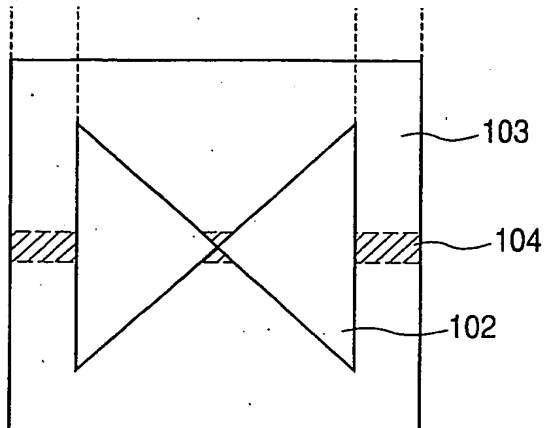
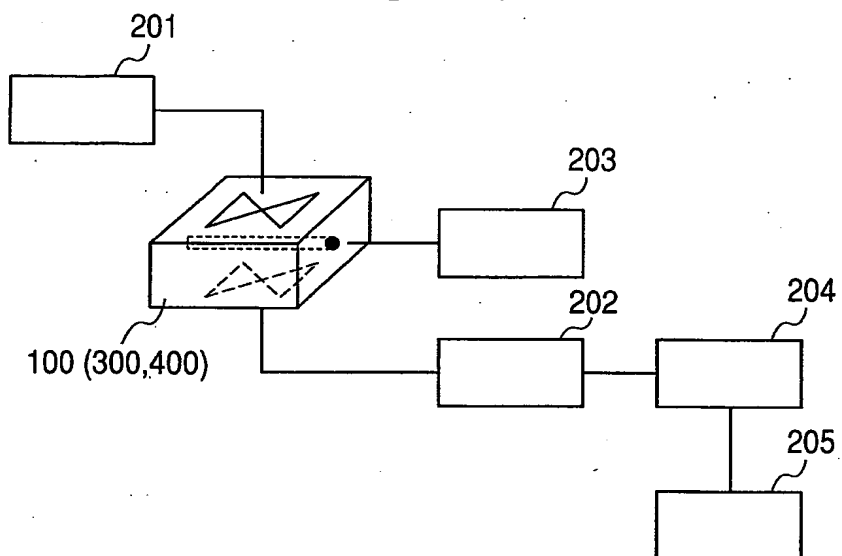
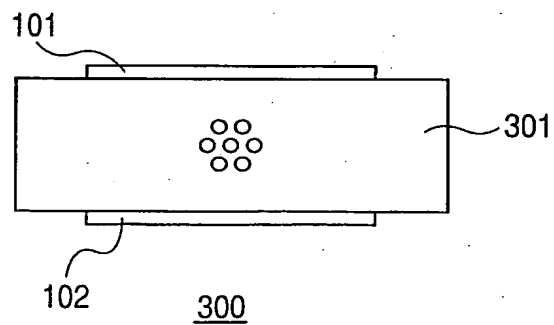


FIG. 1C

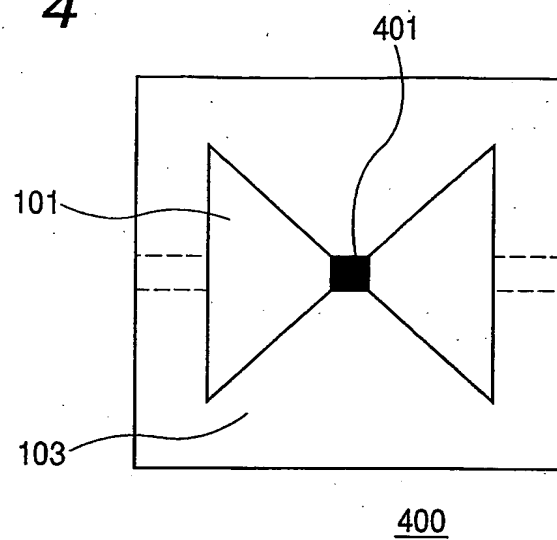
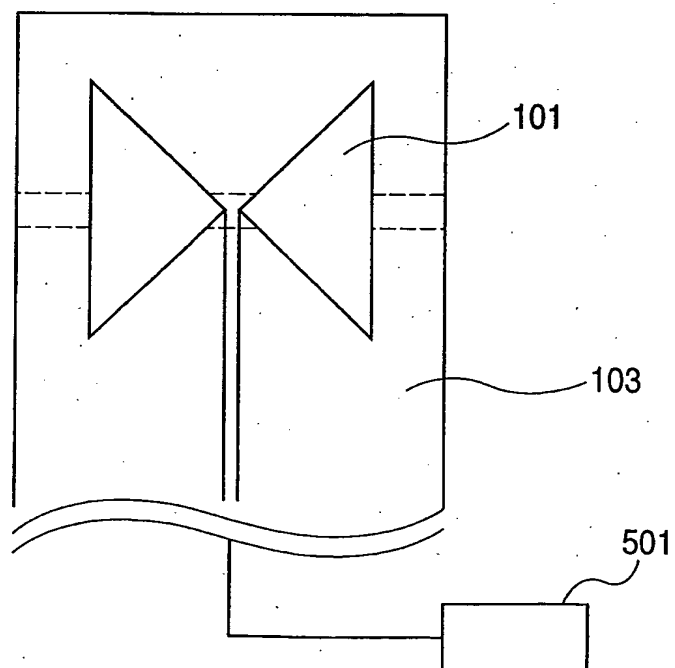


100

2/7

**FIG. 2****FIG. 3**

3/7

**FIG. 4****FIG. 5**

4/7

FIG. 6

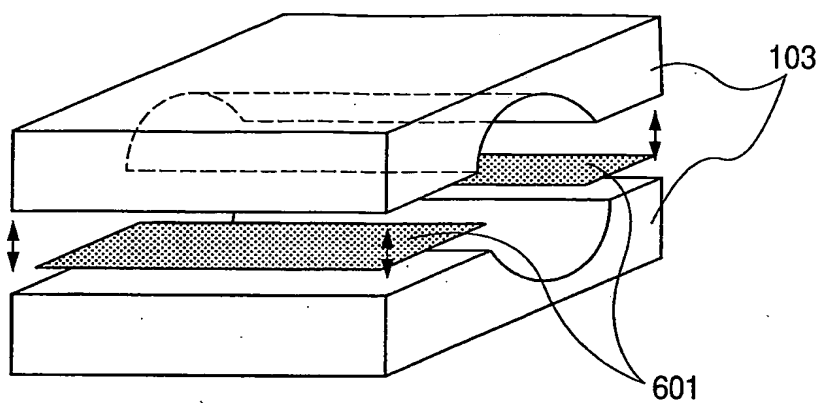
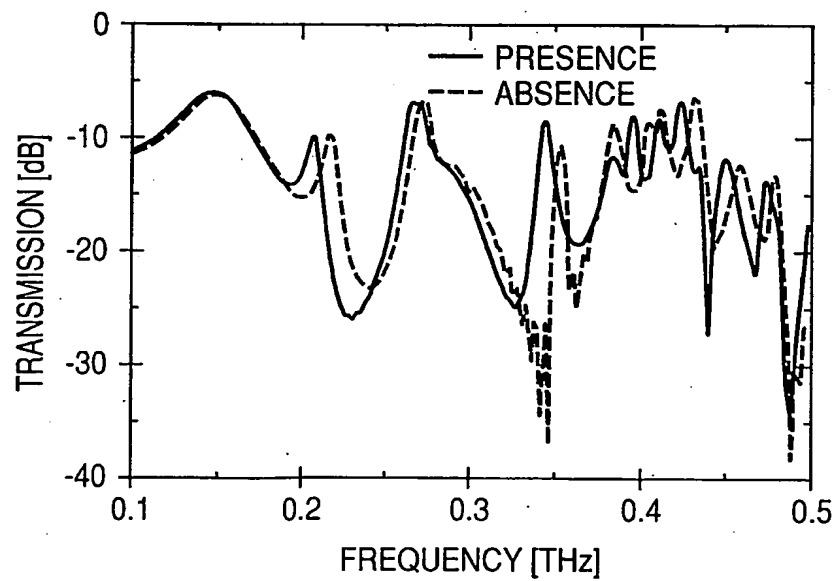
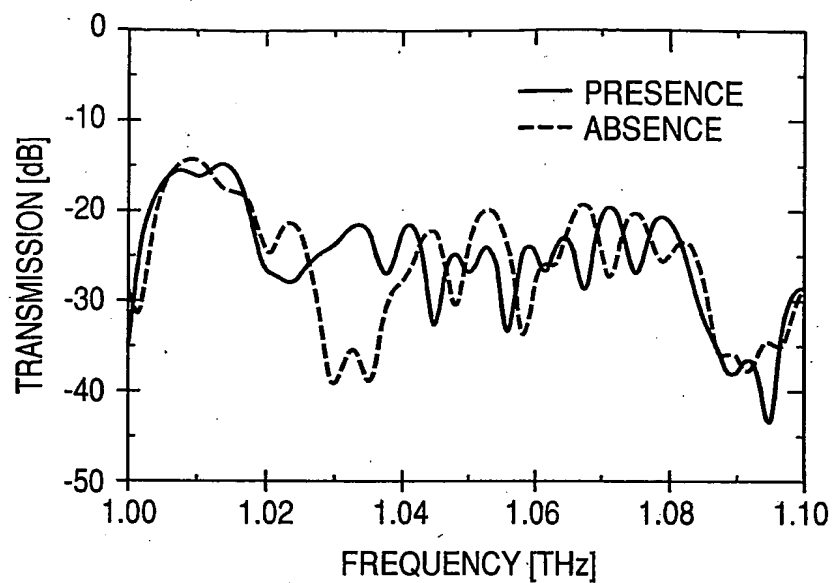
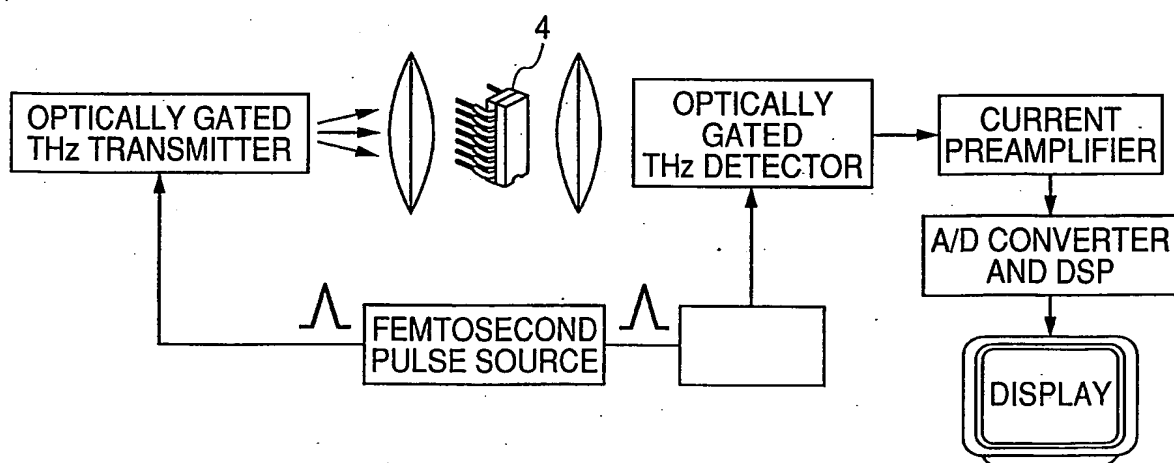


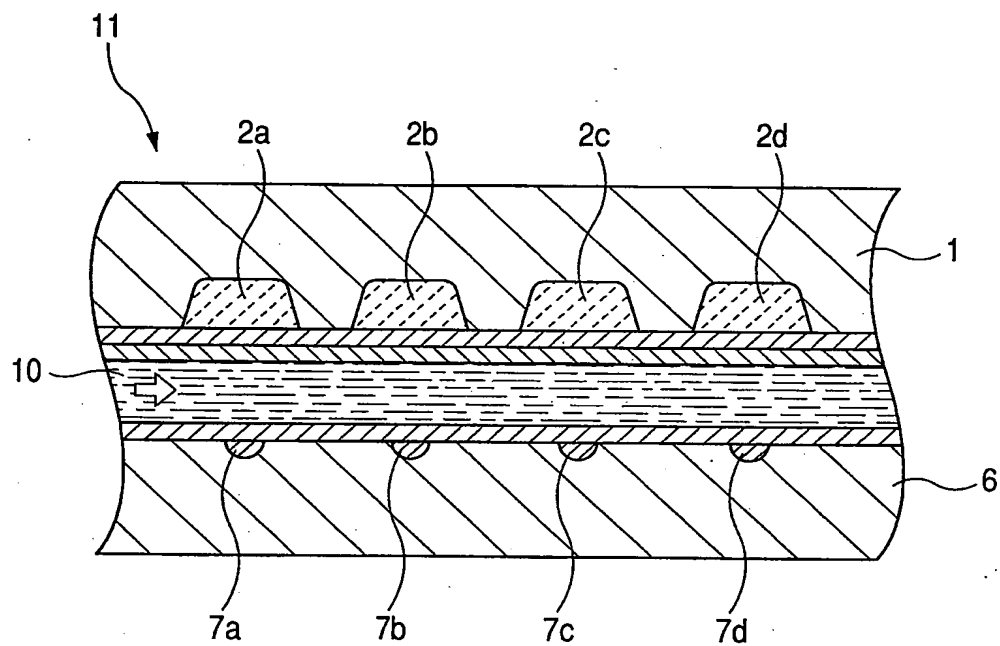
FIG. 7



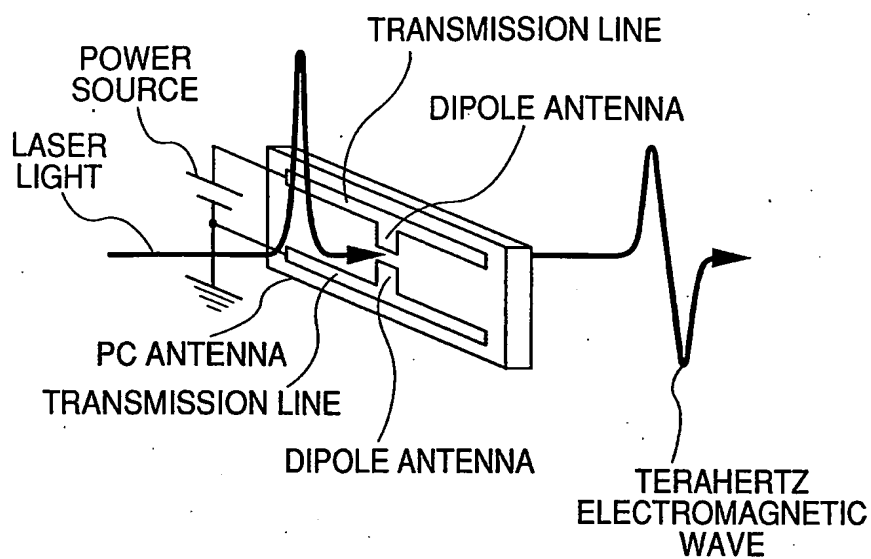


5/7

**FIG. 8****FIG. 9**

**FIG. 10**

7/7

**FIG. 11A****FIG. 11B**